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AUTHOR Heath, John Edwin, Ed.
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ABSTRACT

This paper examines (in separate sections) professional problems, proposed solutions, current trends, and needed directions related to science, mathematics, and technology education in the United States today. Professional problems and related issues focus on students, teachers, curriculum, and college science education programs (the latter listing eight problems, such as an uncertainty about the goals of science education). Proposed solutions to these problems are outlined and discussed as related to curriculum and philosophy; and at the teacher, school district, business, community, university, government, and teacher education program levels. In addition to lists of characteristics of effective schools and of teaching competencies required by teachers of the future, the section on current trends points out several studies/surveys indicating, among other trends, that the desirability of a background in science or mathematics will increase and that, as the number of emergency teachers goes up, the quality of science/mathematics instruction will go down. Needed directions from several sources are outlined and discussed in the final section. Among these directions are those suggesting a new view of science education and measures for eliminating the disparity between salaries of science/mathematics teachers and their counterparts in industry. (JN)

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SCIENCE, MATH, AND TECHNOLOGY

A Crisis in American Education

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edited by

John Edwin Heath

Chemistry Instructor

Southwest Texas Junior College

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INTRODUCTION

Our scientific research and technological activity has been the finest in the world. We now see our technical pre-eminence eroding (Newell, 1983:18). America's declining share of the world market has been particularly dramatic in capital-intensive high-volume industries. Automobile production has declined by almost one third; industrial machinery by 33 percent; agricultural machinery by 40 percent; telecommunications machinery by 50 percent; and metal working machinery by 55 percent. Had we devised technological methods to cut our own labor, energy and raw material costs, we would not be the victims of a trade imbalance today (Hersh, 1983:28). We appear to be raising a generation of Americans who lack the education to participate in a world of technology (Hersh, 1983:27).

Technological literacy is the capacity to use and to work with technology intelligently within a broad context of understanding. It can best be exemplified by a person's knowledge of and willful and intelligent interaction with the use of technology at home and at the work site (Dyrenfurth, 1983:43).

Examples of applied technology can be seen in several places. In the office there are word processors, integrated data generation, analysis, reproduction and communication systems, and computers. In agriculture there is mechanical hardware such as sophisticated analytical and control techniques used for irrigation, fertilization, and damage control. In factories there are robots, computer-assisted manufacturing of products designed by engineers using computer-assisted design and drafting. In hospitals routine diagnosis and treatment are carried out with CAT scans, sonar, laser beams, and fiber optics. In homes there are microwave ovens with magnetic information reading abilities, programmed digital clock radios, automatic temperature and humidity-sensing climate control systems, and satellite-delivered cable entertainment. Under automobile hoods there are many computerized measuring and controlling systems (Dyrenfurth, 1983:43).

Evidence continues to build indicating a deterioration of the quality and quantity of education in mathematics, science, and technology, resulting in a growing chasm between a small scientific and technological elite and a citizenry uninformed on issues with a science component (Newell, 1983:18). Today twice as many students graduate with law and finance degrees than with science and engineering degrees. Most corporate executives hold such degrees. Their education has stressed the manipulation of rules and numbers over sci-

entific solutions to production problems. This oversight has had many repercussions, one of which is our inability to compete successfully in international trade (Hersh, 1983:28).

Many current graduates of American secondary schools do not have the background necessary to be successful in a broad range of technical fields, including the military (McCurdy, 1983:293). In the past, when students did not go on to school after high school, they could always find work in the factory. Now, with robots doing more and more work, there are some real questions developing about how best to use a student's talents after graduation. Science and math must be made an integral part of the basic liberal arts education and people who cannot cope with computers in the near future will be considered illiterate because of the demands of a changing society and business (Newell, 1983:18).

There is an increasing national neglect of human capital resources to meet future industrial, technological, and defense needs. The nation's current shortage of math and science teachers is one small symptom of this neglect (Newell, 1983:11). Foreign students increasingly constitute a major portion of our engineering school enrollments, and they earned one-half of the doctorates granted by American engineering schools in 1981. The Soviet Union is graduating almost 300,000 new engineers a year, many working in defense related jobs. In comparison, the United States graduated about one-fifth of that number last year. The Japanese now

graduate almost two and one-half times more engineers than American Schools produce (Orr, 1983:35).

I. Dwaine Eubanks, chairman of the American Chemical Society Committee on Education, states the level of public concern for quality science teaching has been practically nonexistent; local and state support has been indifferent at best; and the quality and quantity of science knowledge of American youngsters lags behind that of virtually every other advanced nation ("Report of Seventh Biennial Conference on Chemical Education", 1983:3). This paper will attempt to look at professional problems, proposed solutions, current trends, and needed directions related to science, math, and technology education in the United States today.

PROFESSIONAL PROBLEMS

STUDENT PROBLEMS

America appears to be losing ground in qualifying students for middle-level careers in science and engineering. Most high school graduates will become members of the fastest growing majority group in the United States, the scientific and technological illiterate (Hurd, 1983:60). Senator Gary Hart recently said, "Our toughest battles in the future will be mind against mind, not might against might (Hersh, 1983:29). The number of PhDs likely to be produced in the next two years in either physics or the mathematical sciences (excluding computer science) will be less than in the 1950s before Sputnik (Browder, 1982:29).

One-half of our high school students no longer take a mathematics course past the tenth grade (Orr, 1983:25). A National Science Foundation study disclosed that only about 16 percent of United States high school seniors take a year of chemistry and that less than ten percent take physics (Orr, 1983:35).

The "top" or "brightest" high school students do about as well on academic achievement measures now as they ever have (Hurd, 1983:60); however, between 1963 and 1980, mean Scholastic Aptitude Test (SAT) Scores in mathematics dropped 36 points. The number of students scoring in the lowest group

during this same period increased by about 40 percent (Orr, 1983:25).

There are numerous data documenting declining student achievement in mathematics and science. There have been declines in:

1. Science achievement scores of U. S. 17-year-olds as measured in three national assessments (1969, 1973, and 1977);

2. Mathematics scores of 17-year-olds as measured in two national assessments of mathematics (1973, and 1978); the decline was especially severe in the areas of problem-solving and applications of mathematics

3. Mathematical and verbal Scholastic Aptitude Test (SAT) scores of students over an 18-year period through 1980;

4. Students prepared for post secondary study (Nicholson, 1983:347);

Remedial mathematics enrollments at four-year institutions of higher education increased 72 percent between 1975 and 1980 while total student enrollments increased by only seven percent. At public four-year colleges, 25 percent of the mathematics courses are remedial and at community colleges, 42 percent are (Nicholson, 1983:347). Although 55 percent of the graduating seniors from academic programs in the secondary schools have taken three or more years of mathematics, enrollments in remedial mathematics courses in public four-year colleges have increased over 70 percent in the past five years (Hurd, 1983:60).

The International Educational Assessment, which tested 10- and 14-year-olds in 19 countries in such subjects as math, science, reading comprehension, vocabulary, literature, civics, and foreign languages, paints a dismal picture of our current knowledge and thinking levels. In the 19 tests in which the U. S. participated, we never placed first or second but placed last three times and at the bottom of developed countries, including Sweden and Japan, seven times. Sweden and the U. S. took 18 tests in common, and Sweden surpassed us on 12. Japan and the U. S. took six tests in common, and Japan outscored us on all six (Hersh, 1983:27).

The number of 18-year-olds (already down four percent) will decline another 21 percent by 1992 (Orr, 1983:24). We need to utilize our talented young people to greatest advantage. There is a serious shortage of women, Hispanics, and other minorities in technical fields such as math, physics, computer science, and engineering (Burns, 1982:49; McCurdy, 1983:293). Public school mathematics achievement scores and Armed Forces Vocational Aptitude Battery test results, especially on the mechanical and electronics portions, vary significantly by the sex, racial background, and geographic region of those tested (Orr, 1983:24). Wide differences persist in participation and achievement levels among students from different social groups. Approximately 20 percentage points separated the mathematics achievement scores of 17-year-old black and white students on national assessment

tests in both 1973 and 1978. Approximately 15 percentage points separated 17-year-old Hispanics and whites in both years. Between 1973 and 1978, 9-year-old black students showed a definite improvement in performance on mathematics achievement tests, while the average performance of 9-year-old white students declined and that of Hispanics remained constant (Nicholson, 1983:347).

Difficulties confronting Hispanics majoring in engineering fall into three catagories: 1) poor mathematical preparation, 2) poor language skills, 3) conceptual difficulties. Non-minority students tend to outperform the minorities. There is a consistently strong correlation between performance at math tasks and language proficiency measures for Hispanics. This correlation exists even for math tasks that require little language processing for a solution. This correlation does not appear to exist for non-minority students. One authority suggests there may be a threshold level of linguistic competence a bilingual child must reach in order to avoid cognitive deficits (Burns, 1982:50).

Ability may not be the only factor limiting the number of minorities in technical fields. According to research conducted by the Burns group very few Hispanic parents or relatives work in technical fields. The majority of students surveyed made career decisions based on role models presented to them by family, friends, or relatives. There appeared to be

little communication with the high school staff regarding career choices (Burns, 1982:52).

TEACHER PROBLEMS

According to a report issued by the National Academy of Sciences and the National Academy of Engineering, the shortage of qualified mathematics and science teachers is serious. In 1980, 28 states reported a shortage of mathematics teachers, and in 16 states the situation was listed as critical; by 1981, the number of states reporting a shortage had grown to 43. Similar teacher shortages exist for the physical sciences (Newell, 19823:1). During the 1970s, there was a 77 percent decline nationwide in the number of secondary school mathematics teachers being trained and a 65 percent decline in the number of secondary school science teachers being trained. Only 55 percent of the graduates prepared to teach mathematics actually entered the teaching profession. Almost five times more science and mathematics teachers left teaching in 1980 for employment in non-teaching jobs than left because of retirement. Sarah E. Klein, president of the National Science Teachers Association, says, "If the present exodus of qualified science and mathematics teachers from secondary schools continues, the nation will have a net loss of 35 percent by 1992. The declines in qualified science and mathematics teachers have already exceeded enrollment declines by a factor of three." According to a recent article in EDUCATION TIMES, "79 percent of secondary science teachers have not completed a 10-hour workshop in their subject area in over 10 years; 69 percent have never attended a computer

course or workshop: and 40 percent have not attended a course or workshop since they began teaching an average of 16 years ago . . . in a 1981 survey of 60,000 teachers who teach science at least 50 percent . . . were not science majors and 51 percent of elementary school techers had no undergraduate training in science" (Newell, 1983:10).

There is a growing shortage of qualified secondary school mathematics and physical science teachers. In 1981, 43 states (of 45 responding) reported a shortage of mathematics teachers. For physics teachers, 42 states reported such shortages. In the same year, 50 percent of the teachers newly employed nationwide to teach secondary science and mathematics were actually uncertified to teach those subjects. From 1971 to 1980, student teachers in science and mathematics decreased in number, threefold in science and fourfold in mathematics, and only half of them have actually entered the teaching profession. In addition, 25 percent of those currently teaching have stated that they expect to leave the profession in the near future (Nicholson, 1983:348).

In the past decade there has been an average decline of 64 to 78 percent in secondary school science and mathematics teachers. Of those newly employed science and math teachers in 1981, an average 50.2 percent were unqualified in these areas. Of those teaching in elementary schools, 51 percent report no training for teaching science, and 70 percent are without any in-service training (Walgren, 1982:57).

Preliminary conclusions have been drawn by a math/ science task force appointed by the American Federation of Teachers. At this point, the teacher shortage in the cities surveyed does not, for the most part, take the form of slots unfilled. Rather, people may be on temporary licenses or they may be certified but have not majored in math or science. Elementary and junior high school teachers may be asked to teach specialties at one level higher. The number of teachers in these specialities is declining dramatically. At the same time, many teaching in them now are older and anticipate retirement relatively soon. The need to upgrade curriculum in math and science is a matter for widespread concern, and moves are already being made to implement improvements in a number of places. If pressure to upgrade continues, it will create a necessity for additional teachers. Thus, a "hidden shortage" is already in the making. Little seems to be under way to improve the skills for math and science teachers other than the usual in-service programs. Free tuition plans in Florida and New Orleans for just such a purpose are the notable exceptions (Newell, 1983:11:18).

Figures compiled in November, 1982, showed that 40 state departments of education had found shortages of mathematics and physics teachers in the public schools, and 39 had found a shortage of chemistry teachers. Through 1985, New York State has projected a 77 percent decrease in the number of mathematics teachers, a 50 percent decrease in biology, 59

percent in chemistry, 65 percent in physics, and 41 percent in the earth sciences (Watkins, 1983:10).

A survey of more than 450 teachers indicates that 79 percent of the science teachers have not completed a ten-hour course or workshop in over ten years; 69 percent have never attended a computer workshop; 40 percent reported never attending an in-service course or workshop since they began teaching, an average of 16 years; 24 percent indicated they plan to seek employment outside of education (Shymansky, 1982:62).

An increasing number of mathematics and science teachers are leaving their jobs in public schools to take positions with higher salaries in private industry; colleges are not graduating enough new teachers to replace those who are leaving (Orr, 1983:35; Watkins 1983:10). From 1971 to 1980 there was a 79 percent decline in persons pursuing teaching degrees in math and a 64 percent decline in persons pursuing teaching degrees in science (Shymansky, 1982:61).

A survey of 1,000 secondary school administrators indicated that nationwide half of all newly employed science and math teachers for the school year 1981-82 were unqualified to teach science or math (Shymansky, 1982:61). About one-half of public school mathematics teachers are either unqualified or uncertified, currently teaching on emergency certificates (Orr, 1983:25). An NSTA survey of high school principals revealed 50 percent of the science and math teachers were un-

qualified, and principals from the Pacific states indicated 84 percent were unqualified. They hired the unqualified teachers on an emergency basis because no qualified teachers could be found (Neill, 1982:43).

An NSTA survey of science teachers came up with signs of deteriorating Programs:

1. One in four young science teachers plans to leave teaching.

2. Sixty percent of the teachers reported cuts in their budgets for supplies and equipment, at a time when school labs are obsolete and when computers and other modern electronics are essential to an up-to-date curriculum.

3. Seventy-nine percent said they had not completed a single ten-hour course or workshop in more than ten years.

4. Fifty-one percent of the elementary teachers said they had received no undergraduate training in science, and 64 percent said they no longer have science consultants assigned to their schools (Neill, 1982:42).

Between 1971 and 1980, an NSTA survey of 600 colleges and universities with teacher training programs disclosed a 78 percent decline in the average number of math teachers and a 64 percent decline in the average number of science teachers prepared to teach in secondary schools (Neill, 1982:42). An Iowa University survey finds forty states reporting shortages, many critical, of public school mathematics, physics, and chemistry teachers (Orr, 1983:25).

E. W. Ledbetter, using statistics from governmental and professional society reports, has stated the following statistics:

1. There has been a 68 percent reduction in employment of new science teachers since 1971.
2. Forty-five percent of the science and math teachers currently hired are not certified in their areas.
3. The average age of science teachers is 42.
4. Sixteen percent of U. S. secondary students take one course in chemistry, while their Russian counterparts take four years.

A few of the causes for these statistics are:

1. Societal attitudes--an antiscience attitude on the part of the public that science and technology have failed.
2. Teenage employment--75 percent of secondary school students are employed. (This preempts their study time.)
3. Teachers salaries are not competitive with other professions even when adjusted to a 23-month basis ("General Lectures: Looking Ahead, Looking Around, Looking Back," 1983: 4-5).

In 1982, the Association for School, College, and University Staffing documented teacher shortages by region of the country. Serious shortages were reported in the South Central states for chemistry, physics, and math teachers; in Alaska for chemistry and math; and in the Southeast for math (Gerlovich, 1983:56). In Texas and Oklahoma, shortages in chemistry, physics, general science, earth science, and math were reported. In Louisiana, the shortages were in chemistry,

physics, earth science, and math (Gerlovich, 1983:56). The demand for math and science teachers in Idaho, over a five-year period from 1977 through 1982, was consistently greater than the available pool of certified teacher graduates of Idaho teacher education programs. In the last decade the supply of math teachers nationwide declined 78 percent, and the supply of science teachers dropped 64 percent (Heikkinen, 1982:288).

Where teachers are concerned there are several problems affecting participation and achievement of students at all grade levels:

1. Among certified teachers of high school mathematics and science, very few have had the formal educational preparation required to provide students with an understanding of modern technology.

2. There are few available opportunities for certified mathematics and science teachers to update or broaden their skills and backgrounds.

3. There are few in-service programs to certify teachers who are presently not qualified to teach mathematics and science.

4. Most teachers in the primary and middle-school grades have not had training in science and mathematics or courses in methods to teach these subjects.

5. Relatively few people are available outside the classroom to provide quality control or to assist teachers with pedagogical problems (Nicholson, 1983:348).

This year the SAT scores of prospective teachers were the lowest among all professional school entrants. Add to that the fact that teachers' average earning potential is 30

percent lower than that of auto workers or police officers, and it looks like education institutions will have difficulty attracting the academic talent necessary to train students for the future (Hersh, 1983:27).

TEACHING PROBLEMS

Several sources have summarized problems relative to teaching public school science and math. Some of these problems are:

1. The difficulty in finding and keeping high quality science and math teachers;
2. The shortage of time and materials for teaching science;
3. The problem of using curricula developed in the 1960s that have been updated inadequately;
4. The need to improve the way science and math are taught to make them seem more relevant to today's students ("Science and Math Education Problems Analyzed", 1982:12);
5. A decline in interest in the courses among students;
6. Decreased funding and support from local, state, and federal officials;
7. A lack of pressure from parents and the community to upgrade and expand technical instruction in the public schools (Newell, 1983:1);
8. In mathematics, students are taking more semesters of courses, but show an overall decline in achievement;
9. If a reasonable degree of scientific and technological literacy is an expected outcome of a high school education, it is not being achieved (Hurd, 1983:58).

Mathematics and science requirements both for high school graduation and for college entry have generally declined over the past 15 years. Although there are some encouraging signs that this trend is reversing, only about one-third of the nation's 16,000 school districts require more

than one year of high school mathematics and one year of science for graduation (Nicholson, 1983:349). According to the National Academy of Science, only about one-third of our high schools offer enough mathematics courses to qualify a graduate to enter an accredited engineering school (Orr, 1983:25). Only one-third of the 21,000 U. S. high schools teach calculus, and fewer than one-third offer physics courses taught by qualified physics teachers. Many science courses in schools throughout the country are being taught without an adequate laboratory component or with no laboratory at all (Nicholson, 1983:348).

The time available for adequate instruction in U. S. schools is far more limited than in other countries. In the United States the typical school year consists of 180 days, as contrasted with 240 days in Japan. The typical school day is five hours long, compared with six- or eight-hour days in other countries (Nicholson, 1983:348). Our foreign competitors' school year averages about 240 days a year--25 percent more time than is devoted to education in the United States (Orr, 1983:).

CURRICULUM PROBLEMS

The majority of perceived problems in large and small institution studies seem to be symptoms or results of problems rather than problems per se. These groups seem to dwell on problems such as low enrollments, decreased financial support, professional isolation, overloads, administrative trivia, nature of students, etc. Aside from finances and enrollments, the perceived problems reported in the other studies focus upon the philosophical issues such as goals and objectives, theory base, public distrust of science, lack of direction, and professional leadership. Some concern in all groups was expressed for curriculum matters (Bybee, 1982:674;677).

Existing objectives for primary and secondary science education programs are as follows:

1. Concerns for the factual and theoretical (conceptual) knowledge of science;
2. Concerns for the process of scientific investigations and reasoning;
3. Concerns for practical (laboratory) investigations in science;
4. Concerns for attitudes towards science and attitudes associated with science;
5. Concerns for the relation of science to society (Fensham, 1983:5).

Research, curricula, and practices in science education lag behind developments in the philosophy of science (Abimbola, 1983:190). The strongly ahistorical character of

most science curricula and of most science teachers in the past 20 years means that few actual curricula in practice have provided any serious instruction on the rise and fall of differing science world views (Fensham, 1983:6). Many science teachers are indulging in "piloting." By asking the "right" questions verbally and on examination papers, teachers can achieve successful learning in many students. This becomes just talking about rules by both teachers and students, rather than the sort of talk about the same topics which will challenge existing world views, or strengthen and extend them (Fensham, 1983:10). Literacy in the technological age, what some call the postindustrial or information age, not only requires us to read, write and compute well, but to mentally process an overflow of information and to use this information and high-tech machinery to solve complex problems (Hersh, 1983:27).

Enrollments in school subjects are influenced by student attitudes and school requirements. Students do not particularly like science courses, and this dislike is acquired early. By the end of the third grade, nearly half of the students feel that they would not like to take science. Only 21 percent of eighth-grade students have a positive attitude toward science courses, and this percentage remains constant through high school. The popularity of mathematics drops from a high of 48 percent in grade 3 to a low of 18 percent in grade 12. The most frequent question raised by students in

mathematics classes is, "How am I going to use this stuff?" The usual answer: "You will need it to pass the next course." The main reason for not liking science is that there are too many terms to memorize. A widely used life science textbook written for grade 8 contains 2,500 technical terms and unfamiliar words (Hurd, 1983:58;59).

COLLEGE SCIENCE EDUCATION PROGRAM PROBLEMS

Professional problems associated with science education programs in colleges and universities are ranked in the following order:

1. Uncertainty about goals of science education;
2. Lack of leadership;
3. Reduced interest/demand for science education;
4. Financial problems;
5. Problems within teacher education programs such as an overload of paper work, lack of support for science education within the institution, and lack of leadership;
6. Limited dialogue between researchers and practitioners;
7. Declining enrollments;
8. Lack of theoretical base in science education.

These problems were defined by questioning major universities, large institutions, and small institutions (Bybee 1982:675).

PROPOSED SOLUTIONS

CURRICULA AND PHILOSOPHICAL SOLUTIONS

Recent studies of more than 45,000 students showed 13 percent improvement overall and 24 percent higher achievement scores for minority groups when new curricula developed by NSF-sponsored programs of the 1960s were used (Walgren, 1982:57). James A. Shymansky and associates state that increased subject matter competency of the teacher does not lead to increased learning among students when new curriculum materials are used (1985:402). The curricula of the 1960s held the view that "scientific method" comes first, and specific knowledge comes second (Ambibola, 1983:189). However, to prepare children for a technological world, thinking skills and technological attitudes must be developed, and knowledgeable teachers must be available to help them (Hersh, 1983:27).

One of the major solutions to problems dealing with national survival and prosperity involves the reconstruction of the bases of our primary and secondary education to produce a scientifically and technologically competent population (Browder, 1982:28). Teachers, supervisors, and collegiate science educators must develop new goals, with the aid of scientists and technologists, because without cooperation and understanding, new goals will mean nothing (Watson 1982:31).

Philosophy of science, and, in particular, the new philosophy of science, can be used to provide the necessary guidance to upgrade science education research and practice. The new philosophy of science states that the knowledge, beliefs, and theories we hold determine, to a great extent, what we perceive. The effect of this, according to Herbert A. Smith, is that "what a given teacher believes, knows, and does, as well as what he/she does not believe, know and do, represents what science education will be for a given child." Knowledge of the philosophy of science will enable science teachers to know what science they are teaching, and this knowledge will affect all their instructional practices. This is in opposition to the philosophy of the 1960s. Such a perspective might enable science educators and teachers to ask the right questions concerning problems in science curricula. The answers to such questions will enable teachers to arrive at solutions they can live with (Abimbola, 1983:189-191). This is a more content-oriented philosophy, and computers will provide an immense opportunity to develop curricula and instructional approaches that might motivate larger numbers of students and increase the flexibility of the programs available to them (Nicholson, 1983:349).

TEACHER-ORIENTED SOLUTIONS

The mean SAT scores in mathematics rose three points in 1982. This is the first increase in memory, but no indication of a trend (Orr, 1983:36). Richard S. Nicholson states: "We appear to be raising a generation of Americans, many of whom lack the understanding and skills necessary to participate fully in the technological world in which they live and work. Improved preparation of all citizens in the fields of mathematics, science, and technology is essential to the development and maintenance of our nation's economic strength, military security, commitment to the democratic ideal of an informed and participating citizenry, and leadership in mathematics, science, and technology. We must develop and utilize the talents of all Americans, including women and minorities (1983:346).

We cannot expect to have many young faculty joining our ranks; therefore, we must do more to encourage innovation and communication of ideas among ourselves (Paldy, 1983:135). Students like science when they learn about it outside of school: on television, at museums, planetaria, marine worlds, etc. (Hurd, 1983:59). A climate that fosters innovation and development can be created with desire and imagination. Team-taught courses, faculty-to-faculty classroom visit programs, exchange visits to other schools, attending professional meetings in other fields can be stimulating and useful (Paldy, 1983:135).

Counselors and teachers need to offer more information to supplement whatever information students might receive from parents regarding career opportunities. They can use the following methods to supplement career information from other sources:

1. Engage the students in conversations about the possible career options available to them.
2. Write the universities and inquire about academic programs, financial aid packages, and summer programs available to minority students.
3. Stress to the students that a solid mathematical foundation is essential to almost any field.
4. Arrange for field trips to professional facilities, where students can see sophisticated technical operations in action.
5. Nearby companies will often release technical staff for a day to come and describe to students the details of the profession.
6. Minority representatives of Universities can come to speak to students about various technical programs (Burns, 1982:52;54).
7. Make a greater effort to inform students about science teaching as a career (Sousa, 1983:60).

A survey of science education in 19 countries indicated the value of schooling is attested to by the consistent finding of the importance of the amount of time devoted to teaching and learning (academic engaged time, time on task, opportunity to learn, etc.). This is called the Quantitative Theory (or Principle) of Teaching. In short, more teaching leads to more learning (Preece, 1983:69).

Current research indicates more expository (Ausubelian) styles of teaching are appropriate for younger pupils, but more heuristic (Piagetian) styles of teaching are appropriate for older pupils. Either extreme of teacher behavior in a given classroom is likely to be counterproductive due to the mixture of student development levels that exists. This explains why substantial differences in teaching behavior are associated with very small changes in pupil achievement. The maximum change in pupil achievement results in between the two extremes (Preece, 1983:71).

SCHOOL-DISTRICT ORIENTED SOLUTIONS

As the total number of 18-year-olds in the population continues to decrease into the 1990s, the percentage of high school graduates entering pre-professional, college-level courses in science and engineering must increase to meet future manpower needs. Three important goals of the educational system are:

1. To continue to develop and to broaden the pool of students who are well prepared and highly motivated for advanced careers in mathematics, science, and engineering;

2. To widen the range of high-quality educational offerings in mathematics, science, and technology at all grade levels, so that more students will be prepared for and thus have greater options to choose among technically oriented careers and professions;

3. To increase the general mathematics, science, and technology literacy of all citizens for life, work, and full participation in the society of the future (Nicholson, 1983:346);

Latent support for improving science instruction in schools appears to exist; but demonstrated leadership, imagination, and courage are needed before any changes will occur (Watson, 1982:31). The Houston Independent School District has implemented a differential pay plan which rewards teachers who teach in areas of critical teacher shortages. Last year teachers of mathematics, science, bilingual education, special education, and compensatory (Title I) education received $2,000 to $3,000 more per year than the regular sal-

ary schedule. This year the bonus increases to $4,000 (Neill, 1982:45).

To insure that the education field will be able to attract particularly capable and motivated teachers who can transfer an appreciation for learning to their students, schools must incorporate the following into their master plans:

1. Make salaries for all teachers more competitive with other career opportunities.

2. Strengthen courses required to obtain education degrees. These include thorough instruction in all academic areas, in developing thinking skills, and in using technology for classroom instruction.

3. Provide earlier and more frequent teaching experiences for students interested in entering the teaching profession.

4. Keep teachers up to date on educational instruction and technology through in-service training.

5. Promote respect for the teaching profession (Hersh, 1983:29).

6. Provide stipends, scholarships, and offers of "released time" as an incentive for teachers to be retrained (Watkins, 1983:10).

BUSINESS-, COMMUNITY-, AND UNIVERSITY-ORIENTED SOLUTIONS

The types of business and industrial support that have been provided high school science education can be grouped into five categories: personnel, equipment and materials, facilities, employment, and financial. Business and industry support public education for three reasons. It is considered a civic duty, a responsibility to promote career education, and a means by which the needs of business and industry can be communicated (Glass, 1983:93). During the past decade, corporate support of public education has been increasing at a 12 percent growth rate. During 1980, corporate giving reached 2.7 billion dollars, a 12.5 percent increase over 1979. The federal government encourages corporate giving by allowing up to five percent of the pretax income as a tax deduction (Glass, 1983:92).

The AAAS Office of Science and Technology Education will conduct a national effort to improve the quality of science education in America with a $1.67 million grant from Standard Oil Company of Ohio (SOHIO). The grant will support the Science Resources for Schools (SRS) program which is aimed at junior high schools throughout the country. It will provide schools with science resources--information, ideas, and encouragement--to help them upgrade their science education capabilities. SRS will be directed by AAAS chief education officer, F. James Rutherford ("SOHIO Grant Funds Major Science Education Initiative". 1983:161).

As a short-term strategy, state universities, state education agencies, and private corporations could jointly underwrite an intensive retraining program for those teachers presently in "surplus" areas, as well as those currently teaching math and science with an emergency credential (Watkins, 1983:10).

Community advisory boards can be very beneficial to a school's science and math program. With community input into the nature of the science and math programs (helping to determine the broad goals and objectives of the programs), support is not very far behind (Glass, 1983:95).

Greater ties between high school and college are one means of attacking the problem of deterioration of secondary school science and math. Colleges can assist by providing Saturday science seminars, science lecture series, computer workshops for high school teachers, consultants services, and summer practicums for high school juniors and seniors (Ricketts, 1983:92).

GOVERNMENT-ORIENTED SOLUTIONS

Felix E. Browder states, "We live in a world dominated by science and science-based technology and must organize our policies around that central fact . . . our problems in this domain are national and, therefore, can be tackled adequately only at the national level by leadership from the federal government" (1982:30). An expected recommendation of the Reagan Administration's National Commission on Excellence in Education would call on school districts to pay math and science teachers higher salaries than other teachers in order to stop the current brain drain from the classroom to industry and to attract new, well-trained math and science teachers. Other solutions under consideration include the following:

1. A longer school day;
2. Expanded summer school programs;
3. Increased funding to schools for up-to-date equipment and texts;
4. Higher high school graduation requirements;
5. Summer and academic-year courses and workshops for the many marginally qualified teachers now teaching math and science;
6. Mathematics and science specialists in each elementary school;
7. Leadership from the federal government and national groups to set high standards for math and science education in both elementary and secondary schools (Neill, 1982:41,42).

President Reagan is also recommending a 30 percent increase for science and engineering education programs, from the $30 million approved this year (1983) to $39 million, reflecting the Administration's decision to improve mathematic and science education in the public schools by improving teacher training (McDonald, 1983:16).

Last fall several Democratic Congressmen introduced bills to deal with teacher shortage. One would encourage more studevts to become math and science teachers by offering them a loan-forgiveness program. Another would encourage businesses to lend their scientists to the schools as part-time teachers by offering the corporations a tax incentive (Watkins, 1983:10).

House Bill HRB 1310 consolidated two bills introduced earlier this year by Representative Carl D. Perkins, Democrat of Kentucky and Chairman of the Education Panel, and Representative Don Fuqua, Democrat of Florida and Chairman of the Science Committee. The measure, as approved by the House Education Committee, would authorize $300 million for new grants to improve science and mathematics instruction at elementary and secondary schools. Under the program, which would be run by the Department of Education, up to $250 million would go to state education agencies and local districts, and the remaining $50 million would be earmarked for grants to colleges and universities. The higher education programs would include $20 million for scholarships and $17.5 million for

summer institutes to improve teachers skills in science, mathematics, and foreign languages. The bill would also provide $100 million a year for five years for the National Science Foundation to finance fellowships, lab equipment, and research grants, under a program to boost the number and quality of scientists and engineers (Hook, 1983:1;15).

Senate Bill S248, introduced by Senator Pete V. Domenici, Republican of New Mexico, provides merit scholarships of $2,500 per year for students who are preparing to become elementary and secondary school math and science teachers and awards of $5,000 or $10,000 to experienced math and science teachers, administered by the National Science Foundation. The bill also provides $200,000 per year through fiscal 1986 for block grants to the states for improving math and science education in elementary and secondary schools (Long, 1983:21).

TEACHER EDUCATION PROGRAM-ORIENTED SOLUTIONS

Proposed solutions to problems facing science education programs in colleges and universities are as follows:

1. Greater financial support;
2. Need for a theory base in science education;
3. Recognition that science education does enhance basic skills;
4. Need for a definitive set of goals;
5. Return NSF funding for science education activities;
6. Statewide or regional in-service workshops;
7. Need to understand the learning process better;
8. Need for more and better in-service education;
9. Recruit students for science education;
10. Greater incentives to enter the teaching profession;
11. More interaction between college science educators and school science teachers and administrators (Bybee, 1982:676).

CURRENT TRENDS

Since 1965 the percentage of U. S. patents awarded to foreigh nationals has increased about 25 percent. With the increasing emphasis on mathematics, science, and high technology in other parts of the world, this trend may continue (Orr, 1983:35). However, according to the Robot Institute of America, there will be a twelvefold increase in industrial robots in the United States by 1990. The General Electric Company estimates the annual market for industrial robots to be about $4 million today. They project that to grow to $30 billion by 1990. General Electric currently uses 200 industrial robots in their own manufacturing operations. By 1984 they expect to have about 1,000 in operation. The Bureau of Labor Statistics projects almost a million new robot manufacturing jobs by 1990. Telecommunications was a $15 billion business in 1980. An industry study projects growth to more than triple by 1990. A recent survey by the American Electronics Association found that by 1985, the electronics industry plans to double their recruiting of technicians from the military. About 225,000 computers were in use in 1975. By 1985, there are projected to be about 6,000,000 (Orr, 1983:25;35).

Today a background in mathematics or science is desirable in 118 skills and more than 70 percent of the Air Force's enlisted force. Between 1980 and 1982, Army technical

skill requirements increased 34 percent; a further increase is expected. The Navy anticipates a 17 percent growth for people with mathematic, scientific, and technical skills by 1987 (Orr, 1983:25;35).

Several recent studies show that 20 percent of United States growth in per capita income between 1948 and 1973 was due to better education (Hersh, 1983:28). Both our allies and our economic and ideological competitors are moving toward twelve-year programs of public education (Orr, 1983:35). On the other hand, if current trends in the United States continue, the number of emergency teachers will go up; and the quality of math and science instruction will go down (Shymansky, 1982:62). Fletcher G. Watson draws an interesting list of teacher competencies required by the teacher of the future:

> 1. Teachers will have to be trained in more than one scientific discipline and will have to understand the evidence and arguments within the various fields of science.
>
> 2. Teachers will have to be familiar with a wide range of computer equipment and software and will have to know how to interpret diagnostic tests, as well as how to use their own observations.
>
> 3. Teachers will have to know how to referee class discussions to ensure that many viewpoints and ideas are considered (1982:33).

Results of a recent survey by Market Data Retrieval show that more than 30 percent of United States schools are beginning to purchase microcomputers and to use them in instruc-

tion (Hersh, 1983:27). The advent of microcomputers, by encouraging individualized instruction, will foster a revolution. Teachers will lecture only when they introduce a new topic and will hold group discussions only when they summarize a unit. By simulating laboratory work, computers will relieve the pressure on lab time and equipment. Videodiscs will permit study of science at home through pictures, reference materials, films, and other materials (Watson, 1982:33).

Research done by Ronald Edmonds at the Harvard University Graduate School of Education and by John Goodlad at the University of California, Los Angeles, identified the following characteristics of effective schools:

1. Schoolwide academic goals are clearly established.
2. Curriculum is closely linked to these schoolwide goals.
3. Basic rules of conduct are clearly established.
4. Teachers hold high expectations for students and themselves.
5. Teachers check student progress with frequent tests and quizzes.
6. Teachers assign homework frequently and monitor it carefully.
7. Students take responsibility for their own learning and behavior by participating in student government hall monitoring systems and so on.
8. Students spend a great deal of time on actual learning.

9. Teachers choose curriculum materials that match students abilities.

10. Teachers rely on a variety of teaching strategies to help students achieve a high rate of success.

11. Teachers and principals care about students and communicate that message to parents.

12. Principals are strong leaders but listen to and act upon requests from students, teachers, and support staff

13. Parents and community members are encouraged to participate in school activities (Hersh, 1983:28).

NEEDED DIRECTIONS

"If science education is that discipline which studies the interface between science and society . . . that is concerned with the development and maintenance of a scientifically literate populace, then new directions are obviously needed." (Bybee 1982:680).

In his State of the Union address to Congress, President Reagan said, "We Americans are still the technological leaders in many fields. We must keep that edge, and to do so we need to begin renewing the basics, starting with our educational system. While we grew complacent, others have acted." (Long, 1983:21).

NSTA's Project Synthesis Committee has adopted four major goal areas for science curricula--personal needs, society needs, academic needs, and career awareness (Watson, 1982:31).

A synthesis of the recommendations for the future of science education from a variety of studies involve the following:

1. The leadership in science education should begin the task of defining the discipline more explicitly, developing a rational for it, including an elaboration of broad goals.

2. Mechanisms for increased communication among professionals at all levels and with professionals from related disciplines should be developed.

3. With a new view of science education and new mechanisms for communication within the disci-

pline, networks, clearing houses, development centers, evaluation schemes, Chautauqua-type programs, and similar mechanisms for constantly assessing and improving the profession should be established.

4. The full meaning of and new meanings for such terms as science, technology, education, teacher, school, and scientific literacy should be considered anew (Bybee 1982:680).

5. National organizations should work with the president and the congress to monitor the state of science and math educators in order to anticipate and avoid future crises.

6. States should establish advisory committees to assess inconsistencies in the supply and demand of science and math teachers and to develop plans to alleviate such problems on a short and long term basis.

7. States should establish summer institutes and ongoing in-service programs to up grade the knowledge and skills of science and math teachers.

8. Measures must be taken to eliminate the disparity between salaries paid to science and math teachers and those paid to their counterparts in business and industry (Gerlovich, 1983:57).

In attempting to solve the education crisis in math and science in North Carolina, a state advisory committee made the following recommendations:

1. The adoption of incentives to attract and to retain a greater number of science and mathematics teachers;

2. The funding of 200 $1,000 scholarships per year for teachers of mathematics and science, renewable for a second and third year;

3. The funding of eight state grants to school districts which developed local improvement plans;

4. The State Board of Education require all teachers of mathematics and science to be appropriately certified by 1985-86 (Williams, 1982:554;557).

B. Z. Shakhashiri calls for greater efforts in chemistry courses for those who will not be scientists, for the use of computers as aids in teaching and for renewal programs for teachers at all levels. His eight specific challenges for chemistry teachers can be restated and applied to all science teachers:

1. Increase and improve your own knowledge of your discipline.

2. Examine your course material and your teaching strategies.

3. Collaborate with colleagues who teach English and those who teach math to improve students' abilities to communicate well and to handle numbers.

4. Learn how to use a computer and how to use computers in your teaching.

5. Establish professional contact with another science (your specific course or courses) teacher in your area and establish an arrangement to meet at least twice a year to discuss matters related to teaching your course.

6. Spur your local science organizations to conduct programs in your particular discipline.

7. Make presentations to junior high schools or elementary schools in your area.

8. Every month this year do at least one more lecture demonstration than you have been doing ("General Lectures: Looking Ahead, Looking Around, Looking Back", 1983:4).

Do not be in a great hurry to completely disregard curricula advances of the past. A recently completed study of 25 years of research comparing student performance in the "new" science curricula to student performance in traditional courses indicates the "new" secondary science curricula were consistently more effective (Kyle, 1982:49). Characteristics of the traditional curricula are:

1. Were developed or patterned after a pre-1955 program
2. Emphasized knowledge of scientific facts, laws, theories, and applications
3. Used laboratory activities as verification exercises or as secondary applications of concepts previously covered in class

Characteristics of the "new" curricula are:

1. Were developed after 1955
2. Emphasized the nature, structure, and processes of science
3. Integrated laboratory activities into course discussions
4. Emphasized higher cognitive skills and an appreciation and understanding of the nature of science (Kyle, 1982:50)

On a composite basis across all junior high and high school curricula, the average student in the "new" science curricula exceeded the performance of 64 percent of the students in traditional courses (Kyle, 1982:51). James A. Shymanski's group study synthesizes the results of 105 experimental studies involving more than 45,000 students, and 27 different "new" science curricula developed in the 60s.

Across all new science curricula analyzed, students exposed to new science curricula performed better than students in traditional courses in general achievement, analytical skills, process skills, and related skills (reading, mathematics, social studies, and communication), as well as developing a more positive attitude toward science. On a composite basis, the average student in new science curricula exceeded the performance of 63 percent of the students in traditional science courses (1983:387). A study reported in 1983 indicated that participation in the science inquiry lessons facilitated the development of classification and oral communication skills of bilingual children in the third grade. The results indicated significant improvement (Rodriguez, 1983:292). The inquiry approach to science education seems to be more affective on intermediate students than traditional approaches. Moreover this approach seems to be more useful in those situations where high levels of thought, learning experience, and outcome demands are placed upon the subjects (Lott, 1983:445).

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